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# Estimates of Genetic and Phenotypic Parameters of Pelvic Measures, Weight, Height, Calf Birth Weight, and Dystocia in Beef Cattle

Keith E. Gregory
*U.S. Meat Animal Research Center*

Larry V. Cundiff
*U.S. Meat Animal Research Center*, Larry.Cundiff@ars.usda.gov

Robert M. Koch
*University of Nebraska-Lincoln*, rkoch1@unl.edu

# Estimates of Genetic and Phenotypic Parameters of Pelvic Measures, Weight, Height, Calf Birth Weight, and Dystocia in Beef Cattle

**Keith E. Gregory, Larry V. Cundiff, and Robert M. Koch[1]**

## Introduction

Based on requirements for assistance at first parturition as two-year-olds, experimental results document the importance of dystocia in major breeds of *Bos taurus* cattle. In addition to the greater labor and managerial requirements associated with dystocia (calving difficulty), experimental results show that dystocia results in reduced perinatal calf survival and reduced conception rate in females in the subsequent breeding season when dystocia is experienced. There is not agreement on the value of pelvic measures as a predictor of dystocia at first parturition. Information is limited on the genetic relationship between pelvic measures and other factors that may be genetically associated with dystocia. Selection criteria and procedures that have high predictive value for dystocia and can be evaluated prior to an age of one year when selection decisions are normally made are needed to optimally combine information on a series of bioeconomic traits to increase selection response for reducing dystocia without loss in postnatal growth rate. Because most of the selection opportunity in cattle is among males, selection criteria among males must have high predictive value in their female progeny. The purpose of this study was to provide estimates of genetic and phenotypic parameters on a series of bioeconomic traits evaluated at, or prior to, one year of age as a basis for developing selection criteria and procedures that may result in reduced dystocia while maintaining rate of postnatal gain.

## Procedure

*Populations.* Breed groups included in this study were nine purebreeds [e.g., Red Poll (R), Hereford (H), Angus (A), Limousin (L), Braunvieh (B), Pinzgauer (P), Gelbvieh (G), Simmental (S) and Charolais (c)] and three composite populations to which the nine purebreeds contributed, (MARC I = 1/4 B, 1/4 C, 1/4 L, 1/8 H, 1/8 A; MARC II = 1/4 G, 1/4 S, 1/4 H, 1/4 A and MARC III = 1/4 R, 1/4 P, 1/4 H, 1/4 A). Data were collected on $F_1$, $F_2$, $F_3$ and $F_4$ generations from composite MARC I; $F_2$, $F_3$ and $F_4$ generations from composite MARC II and $F_1$, $F_2$, $F_3$ and $F_4$ generations from composite MARC III. The cattle contributing data for this study were in the Germplasm Utilization Project and were born in the years 1983 through 1990.

*Data Collection.* Calves were weighed at birth, at weaning and 140 and 168 days postweaning. Height was measured at 168 days postweaning in both sexes. Pelvic measures (width and height) were recorded 140 days postweaning in both intact males and females at an average age of 320 days. Pelvic measures were taken by two or three experienced technicians in each year. From 1983 through 1985 measures were taken by the Krautman-Litton Pelvic Meter[2] and since 1986 were taken by the Rice Pelvimeter[3].

Calving difficulty was subjectively evaluated using descriptive scores; i.e., 1 = no difficulty, 2 = little difficulty by hand, 3 = little difficulty with calf jack, 4 = slight difficulty with a calf jack, 5 = moderate difficulty with calf jack, 6 = major difficulty with calf jack, 7 = caesarean birth and 8 = abnormal presentation. Percentage calving difficulty was analyzed (scores and 2 = 0; scores 3, 4, 5, 6 and 7 = 1; and scores of 8 were excluded from analyses). Scores of 8 also were excluded from analysis of calving difficulty score.

*Analysis of Data.* The data were analyzed by least-squares mixed model procedures. The models used included the fixed effects of breed group, year of birth, age of dam with date of birth included as a covariate to adjust to a common age. Sire within breed group was treated as a random effect. More information on specific analyses of these data is provided in the section on Results and is reflected by Tables 1 through 12.

Studentized Range as described by Snedecor and Cochran (1980, p. 234) was computed to obtain approximations of differences required for significance among breed group means for the traits evaluated (Tables 1, 2, 3 and 4).

Separate analyses were conducted for the nine purebreeds and the combined generations of the three composite populations. There was no difference between the purebreeds and the three composite populations in either phenotypic or genetic variation for the traits analyzed. Thus, they were treated as 12 breed groups in each analysis.

## Results

Heritability ($h^2$), genetic correlations (rg), and phenotypic correlations (rp) among pelvic height, pelvic width, pelvic area, 368-day weight and 368-day height were estimated on 5,715 female progeny by 552 sires and 4,531 male progeny by 503 sires (Tables 1 and 2). Two analyses were conducted for each sex, i.e., (1) all traits included (Tables 5 and 7) and (2) pelvic measures adjusted by regression to a common weight and height (Tables 6 and 8). Genetic (co)variances were estimated from the sire within breed group variancecomponent for 12 breed groups representing nine purebred and three composite populations. Among females that produced calves as two-yr-olds (2,942 females by 438 sires), (Tables 3 and 4), the traits of calf birth weight, calving difficulty score (1 through 7) and calving difficulty percentage (0 or 1) were added and four separate analyses were conducted: (1) all calves with sex included in the model (Table 9); (2) traits adjusted by regression to a common birth weight (Table 10); (3) females producing female calves (Table 11); and (4) females producing male calves (Table 12).

The $h^2$'s for pelvic measures were greater in males than in females (Tables 5 and 7). The $h^2$'s for pelvic measures were not greatly reduced as a result of adjusting them by regression within breed group to a common weight and height (Tables 5, 6, 7, and 8). The $h^2$'s for pelvic width were greater than $h^2$'s for pelvic height in both analyses for both sexes (Tables 5, 6, 7 and 8). The rg's between pelvic measures and 368-day weight and 368-day height were greater in both males and females than the rp's among these traits (Tables 5 and 7).

Among females that produced calves as two-yr-olds, in the analysis including all calves, the rg's for pelvic width with 368-day weight, 368-day height, calf birth weight and calving difficulty score were, respectively, .57, .72, .38, and -.42

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[1]Gregory is a research geneticist, Genetics and Breeding Research Unit, MARC; Cundiff is the research leader, Genetics and Breeding Research Unit, MARC; and Koch is a professor emeritus of animal science, University of Nebraska-Lincoln.

[2]Jorgensen Laboratories, Inc., 2198 W. 15th St., Loveland, CO 80538.

[3]Lane Mfg., 2075 S. Balentina St., Unit C., Denver, CO 80231.

(Table 9). The rg's of calf birth weight with 368-day weight and 368-day height were, respectively, .40 and .44 but the rg's of 368-day weight and 368-day height with calving difficulty score approached 0 (Table 9). The rg and rp of calf birth weight with calving difficulty score were, respectively, .50 and .51 (Table 9). The rp's of pelvic measures with both measures of dystocia approached 0 (Table 9). Adjusting pelvic measures and measures of dystocia to a common calf birth weight within sex resulted in little increase in the rp's between pelvic measures and measures of dystocia, whereas, the rg of pelvic width with calving difficulty score was increased from -.42 to -.80 (Tables 9 and 10). The rg's between calf birth weight and calving difficulty score were .17 and .70 for females producing female and male calves, respectively (Tables 11 and 12).

The low rp's between pelvic measures and both measures of dystocia (calving difficulty score and calving difficulty percentage) suggest that selecting replacement females based on their pelvic measures at 320 days would have little effect on dystocia of either their male or female progeny at first parturition. The magnitude of the rg's suggests that optimum weighting of pelvic width at 320-days along with 368-day weight and 368-day height with negative weighting of calving difficulty score and calf birth weight in a selection index should result in response to selection for reduced dystocia while maintaining 368-day weight and 368-day height. However, because most of the selection opportunity in cattle is among males, the critical question that is *not* addressed in this study is the rg between pelvic measures in bulls and first parturition dystocia of their daughters.

**Table 1—Number of sires and individuals and least squares breed group means for pelvic measures and size – females**

| Breed group | Number sires | Number individuals | Pelvic height (cm) | Pelvic width (cm) | Pelvic area (cm) | 368-day weight (lb) | 368-day height (in) |
|---|---|---|---|---|---|---|---|
| Overall mean | 552 | 5,715 | 12.8 | 11.2 | 144.2 | 679 | 47.2 |
| Red Poll | 34 | 356 | 12.6 | 11.0 | 138.4 | 633 | 45.7 |
| Hereford | 28 | 334 | 11.8 | 10.3 | 122.9 | 593 | 44.5 |
| Angus | 42 | 400 | 12.1 | 10.2 | 123.7 | 633 | 44.9 |
| Limousin | 36 | 350 | 12.6 | 10.9 | 138.4 | 635 | 47.2 |
| Braunvieh | 39 | 317 | 13.3 | 11.9 | 158.2 | 708 | 48.8 |
| Pinzgauer | 31 | 313 | 13.2 | 11.7 | 155.2 | 706 | 48.4 |
| Gelbvieh | 39 | 325 | 13.0 | 11.6 | 152.0 | 710 | 48.8 |
| Simmental | 37 | 298 | 12.8 | 11.6 | 149.5 | 712 | 49.2 |
| Charolais | 37 | 368 | 13.4 | 11.8 | 157.8 | 719 | 48.8 |
| MARC I | 84 | 869 | 13.1 | 11.6 | 153.1 | 719 | 48.4 |
| MARC II | 79 | 959 | 12.6 | 11.1 | 141.0 | 703 | 47.2 |
| MARC III | 66 | 826 | 12.6 | 11.0 | 140.3 | 681 | 46.1 |
| D.05[a] | | | .21 | .20 | 4.4 | 17.6 | .4 |

[a] D.05 is the approximate difference between breed group means required for significance.

**Table 2—Number of sires and individuals and least squares breed group means for pelvic measures and size - males**

| Breed group | Number sires | Number individuals | Pelvic height (cm) | Pelvic width (cm) | Pelvic area (cm) | 368-day weight (lb) | 368-day height (in) |
|---|---|---|---|---|---|---|---|
| Overall mean | 503 | 4,531 | 12.4 | 11.0 | 136.7 | 891 | 49.2 |
| Red Poll | 29 | 207 | 12.2 | 10.9 | 134.4 | 836 | 48.0 |
| Hereford | 25 | 243 | 11.6 | 10.2 | 119.4 | 763 | 46.1 |
| Angus | 39 | 309 | 11.8 | 10.3 | 122.6 | 800 | 46.4 |
| Limousin | 32 | 254 | 12.6 | 10.9 | 137.8 | 825 | 49.2 |
| Braunvieh | 36 | 220 | 12.5 | 11.4 | 143.6 | 930 | 50.4 |
| Pinzgauer | 27 | 220 | 13.0 | 11.5 | 150.0 | 937 | 49.6 |
| Gelbvieh | 33 | 257 | 12.5 | 11.3 | 141.8 | 955 | 50.4 |
| Simmental | 30 | 225 | 12.6 | 11.3 | 142.7 | 948 | 50.8 |
| Charolais | 35 | 229 | 12.6 | 11.4 | 145.0 | 942 | 50.8 |
| MARC I | 81 | 783 | 12.3 | 11.0 | 136.4 | 917 | 49.6 |
| MARC II | 73 | 910 | 12.2 | 10.8 | 132.5 | 926 | 48.8 |
| MARC III | 63 | 674 | 12.4 | 10.8 | 134.8 | 902 | 48.0 |
| D.05[a] | | | .30 | .27 | 6.33 | 25.1 | .5 |

[a] D.05 is the approximate difference between breed group means required for significance.

**Table 3—Number of sires and individuals and least squares breed group means for calf birth weight and dystocia of females producing calves - sexes combined**

| Breed group | Number sires | Number individuals | Calf birth weight (lb) | Calving difficulty score[a] | Calving difficulty (%)[b] |
|---|---|---|---|---|---|
| Overall mean | 438 | 2,942 | 84.0 | 2.9 | 52.1 |
| Red Poll | 29 | 189 | 77.8 | 2.8 | 58.7 |
| Hereford | 20 | 173 | 75.2 | 2.7 | 48.6 |
| Angus | 37 | 225 | 71.4 | 2.3 | 40.9 |
| Limousin | 28 | 154 | 78.5 | 1.9 | 29.1 |
| Braunvieh | 34 | 182 | 93.5 | 3.8 | 68.9 |
| Pinzgauer | 27 | 179 | 94.4 | 3.7 | 67.9 |
| Gelbvieh | 34 | 193 | 87.3 | 3.4 | 59.9 |
| Simmental | 32 | 165 | 86.2 | 2.9 | 52.0 |
| Charolais | 33 | 177 | 87.3 | 2.3 | 39.0 |
| MARC I | 56 | 424 | 89.7 | 3.1 | 56.7 |
| MARC II | 53 | 405 | 85.8 | 3.1 | 56.3 |
| MARC III | 55 | 476 | 82.0 | 2.7 | 47.3 |
| D.05[c] | | | 3.5 | .60 | 14.5 |

[a] 1 = no difficulty, 2 = little difficulty by hand, 3 = little difficulty with calf jack, 4 = slight difficulty with calf jack, 5 = moderate difficulty with calf jack, 6 = major difficulty with calf jack, 7 = caesarean birth.

[b] Percent requiring assistance.

[c] D.05 is the approximate difference between breed group means required for significance.

**Table 4—Least squares breed group means by sex for calf birth weight and dystocia**

| Breed group | Calf birth wt (lb) | | Calving difficulty score[a] | | Calving difficulty (%)[b] | |
|---|---|---|---|---|---|---|
| | Males | Females | Males | Females | Males | Females |
| Overall mean | 87.1 | 80.9 | 3.4 | 2.3 | 64.6 | 38.8 |
| Red Poll | 80.5 | 75.2 | 3.2 | 2.4 | 68.9 | 47.8 |
| Hereford | 77.4 | 73.0 | 3.4 | 2.0 | 68.9 | 25.1 |
| Angus | 73.4 | 69.2 | 2.7 | 2.0 | 53.3 | 28.3 |
| Limousin | 81.1 | 75.8 | 2.2 | 1.7 | 37.1 | 20.7 |
| Braunvieh | 98.3 | 88.2 | 4.7 | 2.9 | 83.0 | 54.5 |
| Pinzgauer | 97.9 | 90.6 | 4.3 | 3.0 | 79.8 | 55.5 |
| Gelbvieh | 90.6 | 83.8 | 4.2 | 2.6 | 76.5 | 42.3 |
| Simmental | 89.5 | 82.7 | 3.6 | 2.1 | 69.2 | 33.4 |
| Charolais | 89.5 | 85.1 | 2.6 | 2.0 | 45.1 | 31.8 |
| MARC I | 92.6 | 86.6 | 3.6 | 2.6 | 65.9 | 47.1 |
| MARC II | 88.4 | 83.3 | 3.7 | 2.5 | 68.0 | 44.6 |
| MARC III | 85.3 | 78.5 | 3.3 | 2.1 | 60.0 | 34.4 |
| D.05[c] | 4.8 | 4.6 | .9 | .8 | 19.4 | 21.4 |

[a, b, c,] See footnotes for Table 5.

**Table 5—Estimates of heritability ($h^2$) of and genetic (rg) and phenotypic (rp) correlations among pelvic measures and size - females [a,b,c]**

| | Pelvic height (cm) | Pelvic width (cm) | Pelvic area (cm) | 368-day weight (lb) | 368-day height (in) |
|---|---|---|---|---|---|
| Pelvic height (cm) | .14 ± .03 | .64 ± .08 | .88 ± .03 | .46 ± .10 | .70 ± .09 |
| Pelvic width (cm) | .59 | .25 ± .04 | .92 ± .02 | .53 ± .08 | .60 ± .07 |
| Pelvic area (cm) | .88 | .90 | .20 ± .04 | .54 ± .08 | .70 ± .07 |
| 368-d weight (lb) | .33 | .37 | .39 | .32 ± .04 | .72 ± .04 |
| 368-d height (in) | .33 | .35 | .38 | .64 | .44 ± .04 |

[a] Estimates of $h^2$ on diagonal.

[b] Estimates of rg above diagonal.

[c] Estimates of rp below diagonal.

**Table 6—Estimates of heritability ($h^2$) of and genetic (rg) and phenotypic (rp) correlations among pelvic measures – adjusted to common height and weight - females[a,b,c]**

| | Pelvic height (cm) | Pelvic width (cm) | Pelvic area (cm) |
|---|---|---|---|
| Pelvic height (cm) | .08 ± .03 | .44 ± .14 | .79 ± .07 |
| Pelvic width (cm) | .52 | .19 ± .03 | .90 ± .03 |
| Pelvic area (cm) | .86 | .88 | .14 ± .03 |

[a] Estimates of $h^2$ on diagonal.
[b] Estimates of rg above diagonal.
[c] Estimates of rp below diagonal.

**Table 7—Estimates of heritability ($h^2$) of and genetic (rg) and phenotypic (rp) correlations among pelvic measures and size - males[a,b,c]**

| | Pelvic height (cm) | Pelvic width (cm) | Pelvic area (cm) | 368-d weight (lb) | 368-d weight (in) |
|---|---|---|---|---|---|
| Pelvic height (cm) | .46 ± .05 | .80 ± .03 | .93 ± .01 | .31 ± .08 | .42 ± .07 |
| Pelvic width (cm) | .55 | .60 ± .06 | .96 ± .01 | .32 ± .07 | .42 ± .06 |
| Pelvic area (cm) | .91 | .84 | .62 ± .06 | .32 ± .07 | .43 ± .06 |
| 368-d weight (lb) | .28 | .30 | .33 | .42 ± .05 | .62 ± .05 |
| 368-d height (in) | .25 | .21 | .27 | .66 | .55 ± .05 |

[a, b, c] See footnotes for Table 6.

**Table 8—Estimates of hertitability ($h^2$) of and genetic (rg) and phenotypic (rp) correlations among pelvic measures – adjusted to common height and weight – males[a,b,c]**

| | Pelvic height (cm) | Pelvic width (cm) | Pelvic area (cm) |
|---|---|---|---|
| Pelvic height (cm) | .40 ± .05 | .78 ± .04 | .93 ± .01 |
| Pelvic width (cm) | .63 | .52 ± .05 | .96 ± .01 |
| Pelvic area (cm) | .90 | .90 | .54 ± .05 |

[a, b, c] See footnotes for Table 6.

**Table 9—Estimates of heritability ($h^2$) of and genetic (rg) and phenotypic (rp) correlations among pelvic measures, size calf birth weight and dystocia for females producing calves - all calves[a,b,c]**

| | Pelvic height (cm) | Pelvic width (cm) | Pelvic area (cm) | 368-d weight (lb) | 368-d height (in) | birth weight (lb) | Cal Calving difficulty score | Calving difficulty (%) |
|---|---|---|---|---|---|---|---|---|
| Pelvic height (cm) | .17 ± .05 | .62 ± .11 | .86 ± .05 | .55 ± .13 | .79 ± .13 | .70 ± .19 | .10 ± .27 | .02 ± .32 |
| Pelvic width (cm) | .58 | .41 ± .06 | .93 ± .02 | .57 ± .09 | .72 ± .08 | .38 ± .13 | -.42 ± .21 | -.24 ± .25 |
| Pelvic area (cm) | .88 | .89 | .30 ± .06 | .62 ± .09 | .81 ± .09 | .55 ± .14 | -.26 ± .22 | -.19 ± .27 |
| 368-d weight (lb) | .31 | .37 | .39 | .43 ± .06 | .74 ± .06 | .40 ± .12 | .01 ± .19 | .27 ± .24 |
| 368-d height (in) | .32 | .35 | .38 | .62 | .39 ± .06 | .44 ± .12 | .03 ± .19 | .29 ± .25 |
| Calf birth weight (lb) | .12 | .11 | .13 | .23 | .24 | .25 ± .06 | .50 ± .17 | .52 ± .23 |
| Calving difficulty score | -.06 | -.11 | -.09 | .00 | -.06 | .51 | .12 ± .05 | .90 ± .09 |
| Calving difficulty (%) | -.03 | -.08 | -.07 | .01 | -.03 | .40 | .85 | .07 ± .05 |

[a, b, c] See footnotes for Table 6.

**Table 10—Estimates of heritability ($h^2$) of and genetic (rg) and phenotypic (rp) correlations among pelvic measures, size, calf birth weight and dystocia for females producing calves - adjusted to common calf birth weight - all calves[a,b,c]**

| | Pelvic height (cm) | Pelvic width (cm) | Pelvic area (cm) | 368-d weight (lb) | 368-d height (in) | Calving difficulty score | Calving difficulty (%) |
|---|---|---|---|---|---|---|---|
| Pelvic height (cm) | .14 ± .05 | .59 ± .12 | .84 ± .06 | .47 ± .15 | .74 ± .15 | -.47 ± .32 | -.58 ± .44 |
| Pelvic width (cm) | .57 | .39 ± .06 | .93 ± .02 | .53 ± .09 | .69 ± .09 | -.80 ± .26 | -.58 ± .33 |
| Pelvic area (cm) | .87 | .89 | .27 ± .06 | .56 ± .10 | .17 ± .10 | -.77 ± .28 | -.68 ± .38 |
| 368-d weight (lb) | .29 | .36 | .37 | .41 ± .06 | .70 ± .07 | -.29 ± .20 | .01 ± .24 |
| 368-d height (in) | .30 | .33 | .36 | .60 | .36 ± .06 | -.30 ± .14 | .00 ± .25 |
| Calving difficulty score | -.14 | -.19 | -.19 | -.14 | -.14 | .12 ± .05 | .90 ± .11 |
| Calving difficulty (%) | -.09 | -.14 | -.13 | -.09 | -.22 | .82 | .07 ± .05 |

[a] Estimates of $h^2$ on diagonal.
[b] Estimates of rg above diagonal.
[c] Estimates of rp below diagonal.

**Table 11—Estimates of heritability ($h^2$) of and genetic (rg) and phenotypic (rp) correlations among pelvic measures, size, calf birth weight and dystocia - female calves[a,b,c]**

| | Pelvic height (cm) | Pelvic width (cm) | Pelvic area (cm) | 368-d weight (lb) | 368-d height (in) | Calf birth weight (lb) | Calving difficulty score | Calving difficulty (%) |
|---|---|---|---|---|---|---|---|---|
| Pelvic height (cm) | .25 ± .10 | .54 ± .17 | .84 ± .08 | .48 ± .23 | .56 ± .22 | .59 ± .30 | -.03 ± .40 | .00 ± .42 |
| Pelvic width (cm) | .59 | .40 ± .11 | .91 ± .04 | .60 ± .17 | .60 ± .18 | .52 ± .25 | -.30 ± .36 | -.31 ± .38 |
| Pelvic area (cm) | .88 | .90 | .30 ± .11 | .64 ± .19 | .68 ± .19 | .67 ± .28 | -.20 ± .39 | -.21 ± .41 |
| 368-d weight (lb) | .30 | .34 | .36 | .36 ± .11 | .43 ± .18 | .40 ± .24 | .12 ± .34 | .25 ± .37 |
| 368-d height (in) | .34 | .33 | .38 | .60 | .33 ± .11 | .31 ± .25 | -.10 ± .36 | -.08 ± .37 |
| Calf birth weight (lb) | .15 | .10 | .14 | .20 | .23 | .25 ± .10 | .17 ± .38 | .15 ± .41 |
| Calving difficulty score | -.04 | -.08 | -.07 | .00 | -.04 | .46 | .14 ± .10 | 1.02 ± .08 |
| Calving difficulty (%) | -.03 | -.08 | -.06 | .01 | -.01 | .40 | .90 | .13 ± .10 |

[a] Estimates of $h^2$ on diagonal.
[b] Estimates of rg above diagonal.
[c] Estimates of rp below diagonal.

**Table 12—Estimates of heritability ($h^2$) of and genetic (rg) and phenotypic (rp) correlations among pelvic measures, size, calf birth weight and dystocia - male calves[a,b,c]**

| | Pelvic height (cm | Pelvic width (cm) | Pelvic area (cm) | 368-d weight (lb) | 368-d height (in) | Calf birth weight (lb) | Calving difficulty score | Calving difficulty (%) |
|---|---|---|---|---|---|---|---|---|
| Pelvic height (cm) | .17 ± .05 | .62 ± .11 | .86 ± .05 | .55 ± .13 | .79 ± .13 | .70 ± .19 | .10 ± .27 | .02 ± .32 |
| Pelvic height (cm) | .17 ± .09 | .46 ± .19 | .80 ± .09 | .65 ± .22 | .82 ± .23 | .60 ± .33 | .21 ± .37 | .20 ± .51 |
| Pelvic width (cm) | .57 | .44 ± .10 | .91 ± .04 | .58 ± .13 | .73 ± .13 | .41 ± .21 | -.18 ± .25 | -.04 ± .33 |
| Pelvic area (cm) | .87 | .89 | .33 ± .10 | .67 ± .14 | .84 ± .14 | .53 ± .23 | -.07 ± .28 | .02 ± .37 |
| 368-d weight (lb) | .33 | .39 | .41 | .42 ± .10 | .88 ± .08 | .44 ± .19 | -.11 ± .24 | .20 ± .34 |
| 368-d height (in) | .31 | .36 | .38 | .63 | .45 ± .10 | .56 ± .19 | -.20 ± .25 | .20 ± .34 |
| Calf birth weight (lb) | .11 | .12 | .13 | .27 | .25 | .26 ± .10 | .70 ± .19 | .71 ± .33 |
| Calving difficulty score | -.08 | -.13 | -.12 | .01 | -.07 | .54 | .20 ± .09 | .83 ± .15 |
| Calving difficulty (%) | -.04 | -.08 | -.07 | .02 | -.04 | .42 | .84 | .10 ± .09 |

[a] Estimates of $h^2$ on diagonal.
[b] Estimates of rg above diagonal.
[c] Estimates of rp below diagonal.